THE
ROBERT M. BUCHAN
DEPARTMENT OF MINING

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Information for All:
Transforming the Mining Operations Management Paradigm

Herman Aguirre*, Oscar Rielo, Julian Ortiz, Laeeque Daneshmend

Queen's University, Kingston, Ontario, Canada

formerly at *Universidad del Desarrollo, Santiago, Chile

Presentation Outline

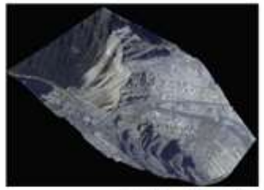
1. Where are we at?

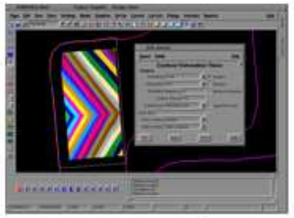
2. How did we get here?

3. Where do we want to get to?

4. How can we get there?

Where are we at?: Fleet Management Systems





ESTIMATED ORE RESERVE/BLOCK MODEL

BLASTHOLES

Mine Plans

Tasks

ESTIMATED ORE BLOCKS Blast Pattern Design

SHORT TERM PLANNING (month)

VULCAN

BENCH ORE MAPS

ORE TYPES

RESERVE ESTIMATION & MINE PLANNING Systems

BLAST DESIGN & SIMULATION – DBS:

BLAST SIMULATION OUTPUT:

- ISSUE DRILLING INSTRUCTIONS
- ISSUE EXPLOSIVE LOADING DESIGNS

HOLE LOCATIONS & ROCK MASS PROPERTIES

GPS GUIDANCE
ROCK RECOGNITION (AQUILA):
Rock mass properties
DRILL CONTROL (ATLAS-COPCO)
PROPEL CONTROL (AC)
LEVELING CONTROL (AC)
TELE-OPERATION (AC)
AUTONOMOUS OPERATION (AC)
HEALTH MONITORING (AC)

RECONCILIATION

BLASTHOLE DRILL Sub-Systems

FLEET MANAGEMENT SYSTEM - DISPATCH™:

MATERIAL TYPES, LOADS, GPS POSITIONS, MACHINE STATE/STATUS, DESTINATIONS; HEALTH & MAINTENANCE (MineCARE™)

RELIABILITY CENTERED MAINTENANCE (RCM)

PLAN

EXECUTE

MONITOR & IMPROVE

HOLE LOCATING VIA GPS
AUTOMATED (CUSTOMIZED) EXPLOSIVE LOADING
EXPLOSIVE INVENTORY & REPORTING (DBS)

EXPLOSIVES LOADING Sub-Systems

CROWD & HOIST
FEEDBACK & CONTROL
GPS GUIDANCE (ELEVATION & 3D ORE CONTROL - CAES)
SWING & TRACK CONTROL (incl. truck spotting)
DIG CONTROL ("AutoDig")

CORRECTED TRUCK LOADS

REAL-TIME INFORMATION

DIPPER WEIGHMENT
DIGGABILITY
CYCLE STATES
HEALTH MONITORING (incl. vibration)

BLAST MOVEMENT MONITORING (BMT)
FACE SCANNING: MATERIAL ID, STRUCTURAL MAPPING (FIXED, UAVs/UGVs)
FRAGMENTATION ANALYSIS (Face, haul-truck bed or dipper)

REMOTE OPERATIONS CENTER:
PRODUCTION & MAINTENANCE PLANNING VISUALIZATION (CAE PS)

EXCAVATOR Sub-Systems

MONITORING Sub-Systems

Where are we at?: Fleet Management Systems

✓Technologically Mature
- Four decades

✓Stable Products

✓Well Supported

✓Feature Rich
- Dispatch Optimization
- Asset Health / Management

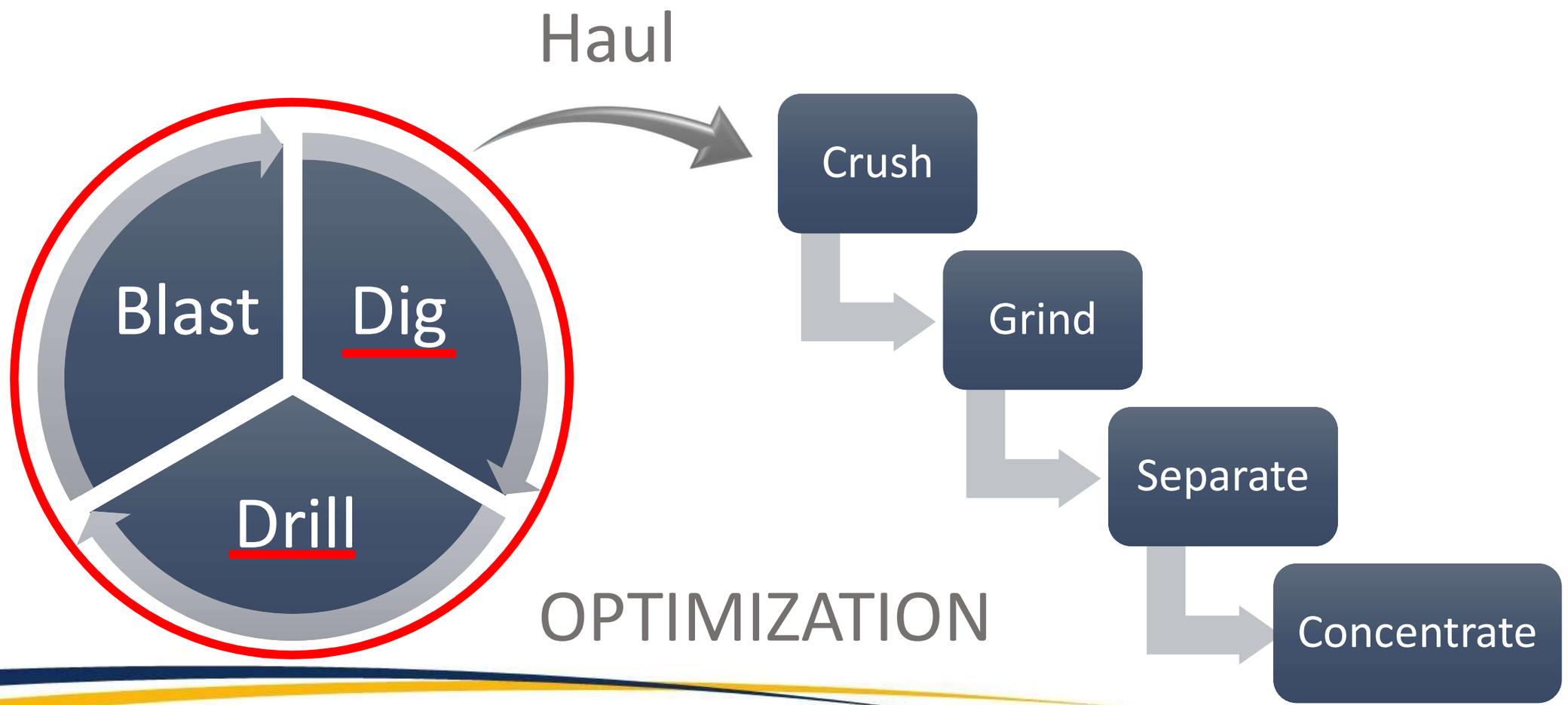
✓Proven Benefits
- At large surface mines
- At large mining companies

X Cost
- Initial Costs
- Operating Costs
- Integration Costs

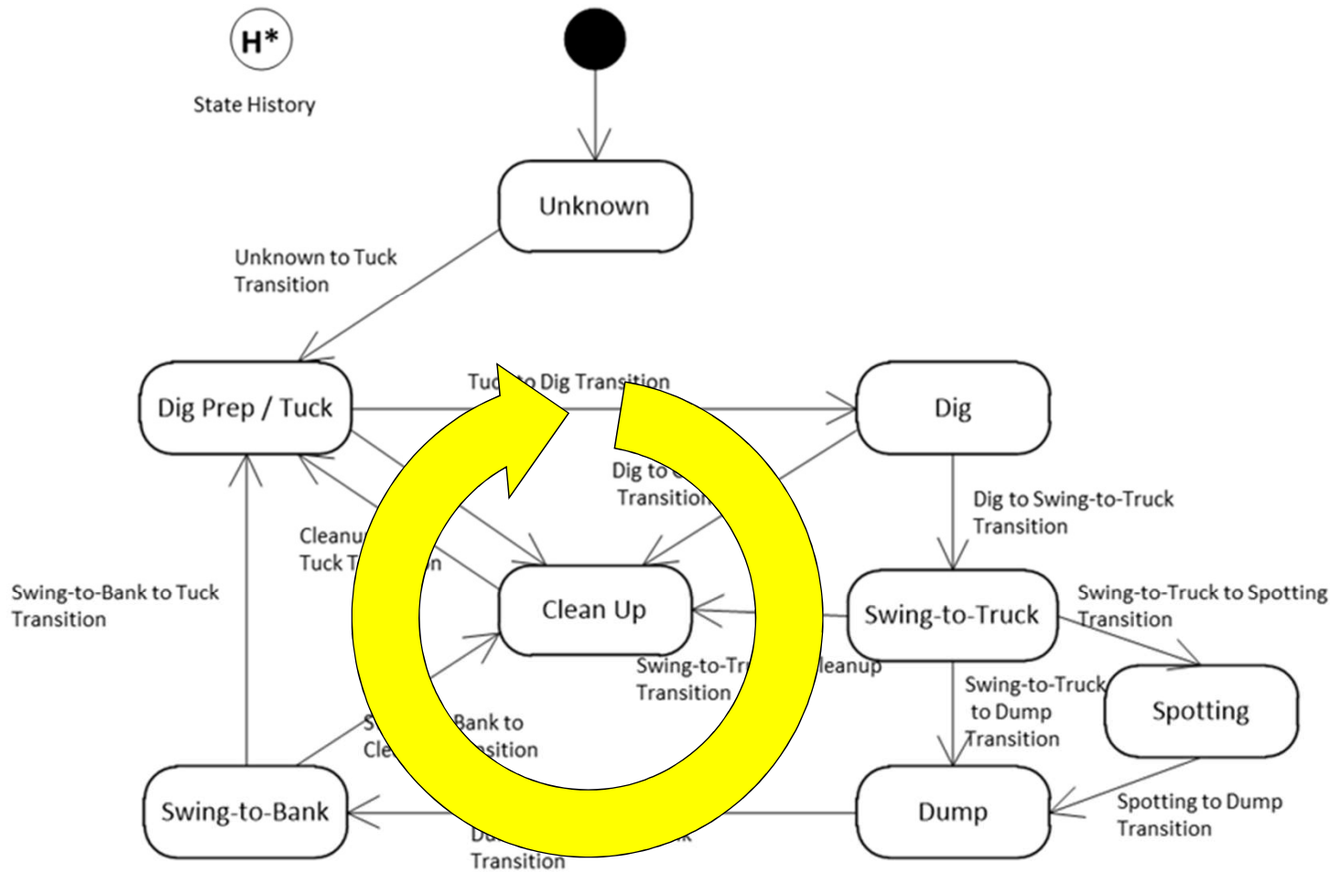
X Other barriers to adoption
- Dependency on operator input
- Technological receptor capacity
- Proprietary data models and interfaces

X Not viable at smaller operations

How did we get here?: Fleet Management Systems Started simple – but grew AMBITIOUS



How did we get here?: Fleet Management Systems Identification of Cycle State Transitions – Cable Shovel Example



How did we get here?: Fleet Management Systems Heavily dependent on Operator Interaction

Where do we want to get to?:
Information for All – Target Market

Where do we want to get to?: Information for All – Target Market

Viable at small operations with

- Small equipment – e.g. 20T trucks, 3 m^3 loaders
- No mine-wide communications infrastructure
- Data connectivity from mine office to outside world
- No on-site hardware or software support personnel
- No personnel available / capable of analysing data / generating reports

Where do we want to get to?:
Information for All – Minimum Functionality

Initial

- Recording of primary Truck and Loader Cycle State-Transitions (Events)
  - With time-stamps and geolocations
  - All without any requirement for operator input/interaction
- Storage of data on trucks and loaders for at least one shift
- “Store-and-Forward” data transfer capability between loaders & trucks
- Offload of data from trucks to mine office via WiFi hub at end of shift
- Upload of data from mine to external cloud-based analytical service provider(s) – for generation of shift / production Reports

Where do we want to get to?: Information for All – Minimum Functionality

Evolving

- Recording of all Cycle State Transitions on all production equipment
  - With time-stamps and geolocations
  - All without any requirement for operator input/interaction
- Recording Machine Health States and Events
- Transfer of data from all other equipment to Trucks
- Storage of data on trucks for at least one shift
- Offload of data from trucks to mine office via WiFi hub at end of each shift
- Upload of data from mine to external cloud-based analytical service provider(s)
  - for generation of shift / production Reports
  - for Mine Planning
  - for Maintenance Management and Machine Diagnostics

Where do we want to get to?: Information for All – Target Cost

- Hardware
  - On mobile equipment: one to two orders of magnitude less than current
  - Infrastructure: so low as to be expendable / negligible
  - Office/Server: negligible
- Software
  - On mobile equipment: practically zero
  - Office/Analysis: at least two orders of magnitude less than current
- Installation & System Integration Costs
  - Negligible

How can we get there?:
Information for All – Guiding Principles for Implementation

Use of low cost, Commercial Off the Shelf (COTS) Hardware for

- Computing elements
- Communication
- Sensors

Open source software for

- Development / Run-Time environment
- Applications

How can we get there?: Information for All – Implementation Agnostic

Data Model completely independent of:

- Hardware Implementation
- Software Implementation

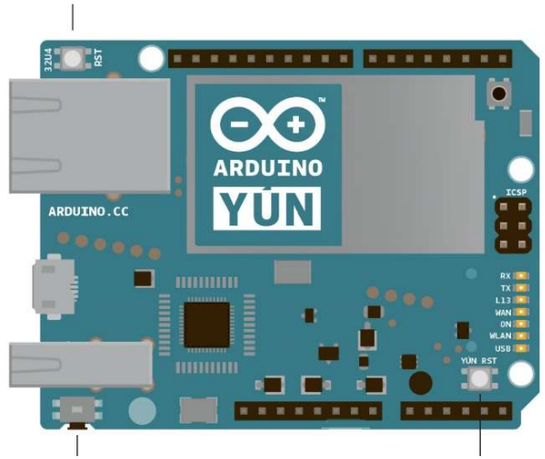
Hardware units become “widgets”

- Interchangeable
- Negligible cost
- Not worth repairing – disposable!

How can we get there?: Implementation – Prototyping

Arduino microcontroller with modules for

- GPS
- WiFi
- RF Proximity



Multipurpose Piezoelectric Sensors – very low cost

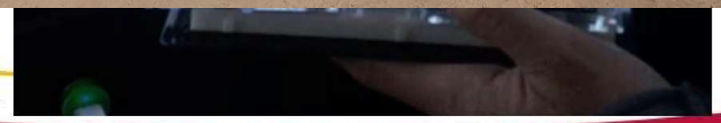
Total cost < US$90 per node

How can we get there?: Implementation – Proof of Concept

Small copper mine in Chile

Tested:

- Software Logic
- GPS module Performance
- WiFi Connectivity
- RF Proximity Detection



How can we get there?:
Next Steps – Formalize the Data Model

Must be

- Non-Proprietary
- Open, Expandable
- Backward compatible

Do NOT reinvent the wheel…

- Use existing forums / organizations to develop open data model
  - Global Mining Standards & Guidelines (GMSG) Group?

CONCLUSION – Why Bother?

Potential to:

- Lower unit costs for deployed hardware & software by up to two orders of magnitude
- Minimize need for technical expertise at mine sites
- Transfer data analytics to the cloud
- Make adoption of mine operations management systems feasible for a much wider range of mine sites, including small and medium sized operations
- Enable development of a highly competitive global marketplace in customised data analytics, with expanded access for data aggregation across numerous disparate sites
- Significantly enhance reporting and analysis capabilities at smaller mine site, at reduced cost

Queen's University

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Questions?